ROOT LENGTH, SURFACE AND DIAMETER OF WINTER WHEAT ALONG SOIL PROFILE

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Winter wheat root length (RL) and root surface (RS) distribution in soil profile during spring was determined in two year field experiments on sandy loam soil (eutric cambisol) at Pernolec (elev. 530 m, precipitation per year 624 mm, average temperature 6.4 °C). Two treatments, unfertilized with N (N0) and fertilized with 40 kg N/ha in early spring (N1), were evaluated. The observed root diameters (RD), averaged over a soil layer, were in the range 0.21–0.37 mm (Tab. I). RL and RS decreased exponentially from surface layers to subsoil (Fig. 1A–C). Total RL per square meter in the early spring, at the end of tillering and at heading reached on average 0.47 km, 4.9 km, 7.8 km, resp., in 1993, and 0.3 km, 5.4 km and 14.9 km, resp., in 1994.

root length; root diameter; root surface; nitrogen fertilization; soil profile; winter wheat

INTRODUCTION

Root distribution and uptake activity must be known to describe water and nutrient uptake from soil reliably. Generally, amount of roots decreases exponentially from superficial soil layers to rooting depth as a result of inherited growth pattern and (usually) better growth conditions in the arable layer (Russell, 1977; Kuhlman, Barraclough, 1987, and others). Root distribution in a certain growth stage is the result of interactions between genotype, soil environment and actual weather conditions. Soil sources, water and nutrients, are distributed non-homogenously in the soil profile, as well. Their amount and availability change substantially during growth period. The amount of water and nutrients depleted by a crop from specific soil depth depends on root and sources distribution, plant development and growth condition in soil and aerial environment (e.g.: Robinson et al., 1991).

The root distribution is described by root weight, length or surface. Although correlation exists among these parameters, root length and surface are preferred to weight when depletion of water and nutrients from soil profile is considered. As experimental determination of root surface is unreliable, mean value of root diameter and root length are employed to calculate root surface (e.g.: Hacket, 1969). Root diameter is important root trait related to the extent of area of nutrient and water depletion around roots and the ability of a root to penetrate soil.

The aim of the study was to quantify the root length, diameter and surface distribution of winter wheat in a soil profile in field.

MATERIAL AND METHODS

Winter wheat root length (RL), surface (RS) and diameter (RD) distribution in soil profile during spring was determined in two year field experiments on sandy loam soil (eutric cambisol) in experimental station of RICP Pernolec (elev. 530 m, precipitation per year 624 mm, average temperature 6.4 °C). Two treatments were used: unfertilized with N (treatment N0) and fertilized with 40 kg N.ha^{-1} in early spring and with 40 kg N (1993) or 50 kg N.ha^{-1} (1994) at the start of stem elongation (treatment N1) (Růžek, 1993; Haberle et al., 1996).

The soil was sampled by 10 cm increments to 40 cm depth with steel cylinder (8.5 cm diameter). Samples from deeper layers, under 40 cm, were taken with soil corer (3.5 cm diam.); two subsamples from each hole formed by 8.5 cm cylinder were bulked together. From six replications per treatment, four soil cores were taken from the row centre and two from midway between the rows. The row spacing was 12.5 cm. The soil was sampled in early spring – before nitrogen fertilization (the start of tillering), the end of tillering and at heading. Roots were washed on sieves and preserved frozen. The complete mixture of plant roots, organical debris and fine sand particles picked up on 0.25 mm sieve was preserved to decrease the loss of the thinnest roots. Roots were cleaned, root length was determined manually after Tennant (1975), root diameter of 20 to 60 roots per sample, randomly selected, were measured with microscope. Root surface was calculated from length and average root diameter. The results of root length and diameter were analysed by ANOVA. Mean values of root traits averaged over the position of the sampler (i.e in a row and row spacing) are presented.

RESULTS AND DISCUSSION

Root length density (i.e. root length in a soil volume) and root surface density along soil profile are shown in Figs. 1A (early spring, start of tillering), 1B (end of tillering) and 1C (heading). Mean values of results obtained in a row and from row spacing are presented. Root length and root surface decreased approximately exponentially from surface layers to subsoil as ob-

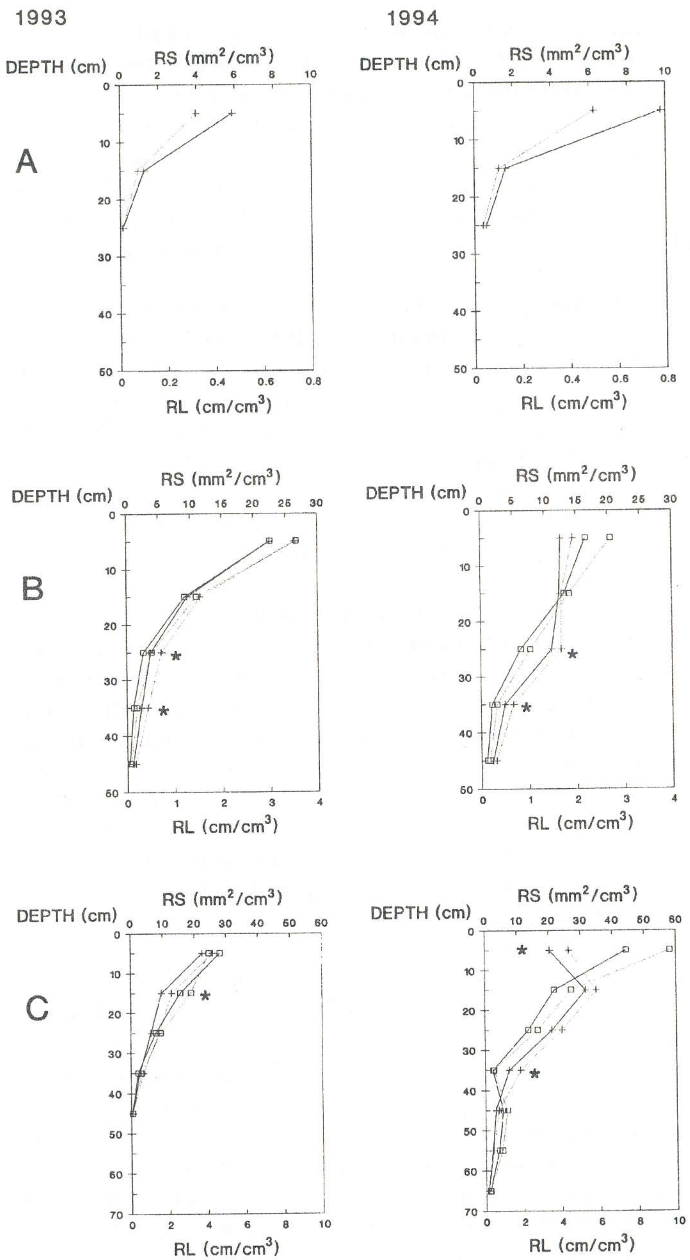
served in most root experiments in field (Barraclough, 1984 and others). As shown in Figs. 1A–C, root length and root surface profiles were similar. Nitrogen fertilization increased root length and surface significantly only in heading in upper layers of soil profile (Fig. 1C). The opposite effect of nitrogen was observed in subarable layers at the end of tillering (Fig. 1B).

Low root densities in layer 50–60 cm, 0.05 cm.cm^{-3} (1993) and 0.15 cm.cm^{-3} (1994) at heading suggest that in that period wheat crop had no good access to nitrate washed to deeper layers (Haberle et al., 1996). However, even small proportion of total root length in deep soil zones can contribute, on some specific conditions, to total water and nutrient consumption (Burns, 1980; Kuhlman et al., 1989; Robinson et al., 1994).

In 1993, total root length per square meter of soil reached on average 0.47 km at the start of spring regeneration (29-03), 4.9 km at the end of tillering (26-04) and 7.8 km at heading (31-05). In 1994 they were 0.3 km (03-03), 5.4 km (19-04) and 14.9 km (01-06), resp. The root length at heading in 1994 is comparable with published data (e.g.: Welbank et al., 1974; Seward et al., 1990); values over 20 km.m^{-2} were found at high-yielding wheat crops at anthesis (Barraclough, Leigh, 1994; Barraclough, 1984).

The great difference of total root length and surface between 1993 and 1994 at heading are likely because of impaired wheat growth in 1993 due to weather conditions. There was extremely cold and dry winter and spring in 1993, (92 mm of precipitation from January to May), in contrast with warmer season and 223 mm of precipitation evenly distributed through the above period in 1994. The grain yield per hectare reached 1.8 t (N0) and 3.0 t (N1) in 1993, and 4.1 t (N0) a 6.4 t (N1) in 1994. It corresponds with the results of Barraclough and Leigh (1984), which found positive relationship between winter wheat above-ground and grain yield and total root length at anthesis. Inter-year differences in wheat growth observed in our experiment were reflected in depletion of Nanorg from soil between tillering and heading (Haberle et al., 1996).

The application of nitrogen fertilization had no significant effect on root diameter according to analysis of variance. Observed root diameters, averaged over a soil layer, were in the range 0.21–0.37 mm (Tab. I). Mean values of root diameter averaged over position of a sampler are presented as we did not find significant differences among root diameters in respect to position of the sampler in the row or between them (not shown). We observed thicker root axis (over 1 mm) in surface 10 cm layer sampled in the row in comparison with those taken from midway between the rows. However, it did not increase average root diameter due to simultaneous proliferation of thin lateral roots. Greater root diameters observed in subsoil were caused by preva-



1A–C. Wheat root length (—— RL) and root surface (- - - - RS) per cubic centimeter of soil at the start of tillering in early spring (1A), at the end of tillering (1B) and in heading (1C). Experimental station Pernolec, 1993 and 1994. Without nitrogen fertilizing (+ N0) and fertilized with 40 kg $N.ha^{-1}$ (□ N1) in early spring. Star symbols indicate significant differences in RL between treatments (ANOVA, $P < 0.05$)

I. Average root diameters of winter wheat along soil profile (in µm) on three sampling terms; N0 – without N fertilizing, N1 – fertilized with 40 kg $N.ha^{-1}$ in early spring; numbers within each column followed by the same letter are not significantly different ($P < 0.05$)

Soil depth (cm)	Term of sampling									
	1993					1994				
	29-03	26-4		31-5		3-3	19-4		01-06	
	N0	N0	N1	N0	N1	N0	N0	N1	N0	N1
0–10	269	280a	282a	219a	201a	255	275ab	295b	247ab	250b
10–20	300	291a	288a	253ab	233a	310	246a	252a	211a	238ab
20–30	333	350b	355b	266b	229a	290	271ab	295b	220a	233ab
30–40	–	343b	375b	271b	296b	–	324b	249a	283b	220ab
40–50	–	341b	369b	272b	211a	–	304b	349c	244ab	236ab
50–60	–	–	–	–	–	–	–	–	207a	238ab
60–70	–	–	–	–	–	–	–	–	264b	207a

lence of unbranched, young root axes. Over hundred per cent difference in mean root diameters between arable and subsoil layers can be inferred from data on wheat root specific length published by Welbank et al. (1974).

Root diameters found in our experiment (Tab. 1) were in upper range of data given in literature (Barley, 1967; DeWilligen, VanNoordwijk, 1987). Root diameters about 0.3 mm were observed in spring wheat, oats and barley (Hackett, 1969; Keita, Steffens, 1989). Several authors reported average diameter of wheat near 0.2 mm (Kuhlman et al., 1989; Seward et al., 1990) or even less (Robinson et al., 1994). Soil texture composition of experimental site with 36% of coarse fraction (0.25–2.0 mm) and 16% of skeleton (Růžek, 1993) might caused higher values of root diameter observed in our experiment. Some adverse soil physical conditions, especially soil compaction, and coarse sand substrates result in changes (mostly increase) in root diameter (e.g.: Russell, 1977; Keita, Steffens, 1989). Also, soil nutrient, water status and soil acidity are known that they affect root diameter (e.g. Hackett, 1972). However, only slightly less root diameters of the same cultivar of winter wheat in fertile loess brown soil were observed at Ruzyně in Prague, the site with warmer climate (unpublished).

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HABERLE, J. – SVOBODA, P. (Výzkumný ústav rostlinné výroby, Praha-Ruzyně, Česká republika):

Délka, povrch a průměr kořenů ozimé pšenice v půdním profilu.

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Ve dvouletém polním pokusu byla zjišťována délka a povrch kořenů ozimé pšenice ve vrstvách půdního profilu. Pokus probíhal v letech 1993 a 1994 v Pernolci u Tachova (hlinitopísčitá půda, 530 m n.v., 624 mm srážek, 6,4 °C). Pšenice byla hnojena regenerační dávkou 40 kg N/ha v předjaří a 40 kg N/ha (1993) nebo 53 kg N/ha (1994) na začátku sloupkování (varianta N1) nebo nebyla dusíkem hnojena (varianta N0) (Růžek, 1993; Haberle et al., 1996). Vzorky prokořeněné půdy byly odebírány sondou o průměru 8,5 cm (do hloubky 40 cm) a 3,5 cm (pod 40 cm), ve čtyřech opakováních na řádku a dvou opakováních v meziřadí, v období jarní regenerace rostlin (začátek odnožování), na konci odnožování a v metání. Kořeny byly vyplaveny na sítech a uchovávány před dočištěním a měřením při teplotě –18 °C. Byla určována délka a průměr kořenů. Povrch kořenů byl vypočítán z délky kořenů a střední hodnoty průměru kořenů ve vzorku. Jsou prezentovány průměrné hodnoty pro variantu N0 a N1. Aplikace dusíku zvýšila průkazně délku kořenů pšenice v povrchové vrstvě 0–10 cm (1994) a 10–20 cm (1993) ve fázi metání a snížila délku kořenů v hlubších vrstvách na konci odnožování (obr. 1B a 1C). Vliv hnojení dusíkem na průměr kořenů nebyl statisticky průkazný. Délka a povrch kořenů se snižovaly přibližně exponenciálně s hloubkou (obr. 1A–C). Distribuce délky a povrchu kořenů v půdním profilu byla podobná. Vyšší průměr kořenů v nejhlubších vrstvách půdního profilu, daný vyšším podílem nevětvených kořenových os, a menší průměr kořenů v orniční vrstvě nezměnily výrazněji tvar rozdělení povrchu kořenů v profilu ve srovnání s délkou kořenů. Zjištěné hodnoty průměru kořenů se nacházely v rozmezí 0,21–0,37 mm. Většina publikovaných údajů se pohybuje okolo hodnoty 0,2 mm. Diskutují se možné příčiny zjištěných vyšších hodnot průměru kořenů. Celková délka kořenů na 1 m^2 půdy byla v roce 1993 0,47 km na počátku jarní regenerace rostlin (29. 3.), 4,9 km na konci odnožování (26. 4.) a 7,8 km ve fázi metání (31. 5.). V roce 1994 to bylo 0,3 km (3. 3.), 5,4 km (19. 4.) a 14,9 km (1. 6.) na počátku metání. Důvodem téměř poloviční délky kořenů v roce 1993 oproti roku 1994 byla pravděpodobně suchá, chladná zima a jaro roku 1993 (92 mm srážek od

ledna do května) oproti teplejšímu roku 1994, s rovnoměrně rozloženými srážkami (223 mm) a menší počet rostlin i stébel. V roce 1993 byla o 100 % nižší produkce nadzemní biomasy a výnos zrna oproti roku 1994.

délka kořenů; povrch kořenů; průměr kořenů; hnojení dusíkem; půdní profil; ozimá pšenice

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